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[57]申請專利範圍：

1. 一種改良之變壓器鐵心，其具有對接與搭接之變壓器鐵心接點，該變壓器鐵心接點包含許多自繞在螺旋體狀之連續膜上偏向割切之疊層割切。該割切之疊層在線圈裝置套入該鐵心後在其末端以對接方式重新連接起來，該多數疊層被分成多粒疊層組，每組含預定數目之疊層，該傾斜割切可防止在線圈裝置套入後及在對接接點之相鄰磁通路徑延長後該鐵心裝配時對接疊層之末端之不良匹配；該鐵心之形成係以螺旋體之構型之疊層組相互加於其上，交互組疊層內之傾斜割切與疊層之縱向中心線成一預定之傾斜，在插入組上之傾斜割切則與該疊層之中心線成相反方向之傾斜。

2. 根據申請專利範圍第1項之鐵心，其中疊層之每組被次分為多級，而每組之疊層中之傾斜割切含在同一斜度之多數逐級之割切。

3. 根據申請專利範圍第1項之鐵心，其中疊層之各組被次分為許多級，在另組疊層中之傾斜割切包含預定傾斜之許多逐級割切，在每一插入組之疊層中之傾斜割切含許多與該個定傾斜成反向之逐級割切。

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4. 一種含套入其上之線圈鐵心的變壓器，該鐵心包含很薄的非晶金屬之疊層繞成螺旋形並構成具有一窗之閉合曲線結構，該線圈裝置繞成圍繞鐵心之一體結構，該鐵心
5. 具有對接及搭接之接點可使該鐵心之開口將該線圈插入，並在該線圈裝置插在其上時使該鐵心再閉合，該對接及搭接之形成係連續以逐級關係割切各組之疊層，每組包括預定數目之疊層以打開該鐵心，並將
10. 每組之割切疊層之末端鄰接以在線圈裝置套入其上後再閉合該鐵心，在該疊層中之割切以與該疊層縱向中心線成一稍不同於90°之第一預定角傾斜，在該連續中之另外各組之疊層以與該預定角度以第二預定
15. 角即在該另組間插入組之縱向中心線以稍不同於90°之角度反向傾斜。

5. 根據申請專利範圍第4項之變壓器，其中另組之每一組及插入組被次分為許多級，在每組中疊層中之割切包含在每組之各級
20. 中疊層之逐級割切，每組逐級割切疊層之中心線之角度及傾斜均為相同。

6. 一種製造變壓器之方法，變壓器具有鐵心及線圈裝置，線圈之各匝繞在一積體線圈

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所增加。

10. 根據申請專利範圍第1項之鐵心，其中其他組彎曲割切之傾斜角及插入組之傾斜角相等而方向相反，並以少許幅度偏離中心線90度角。

11. 根據申請專利範圍第1項之鐵心，其中之鐵心之形成係將連續疊層組相互加在其上成螺旋之構形，至少在其他組間之各組之彎曲割切對膜中心線以稍不同於90度角傾斜。

12. 根據申請專利範圍第4項之變壓器，其中之交互組及插入組之彎曲割切之傾斜角事實上相等而相反並以小幅度與中心線離開90度角。

13. 根據申請專利範圍第7項之方法，其中第一個割切及第二個割切傾斜角相等而相反並以小幅度與膜中心線離開90度角。

圖示簡單說明：

圖1係以相同大小圖解式顯示實行本發明之裝置以產生在偏向疊層縱軸中心線一方向之疊層之割切。

圖2為與圖1之裝置相似，以在與偏向縱軸中心線相反之方向產生疊層之割切；

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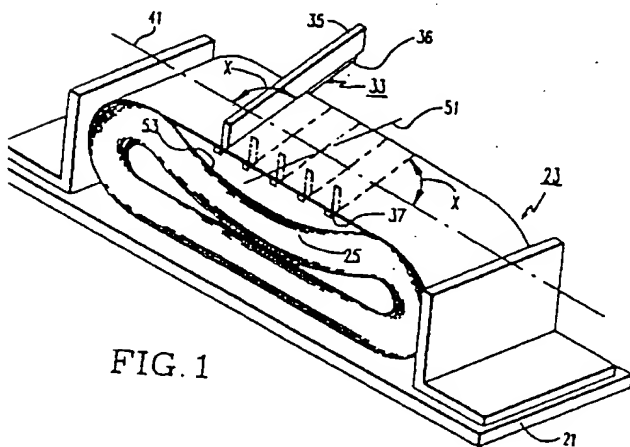
圖3為圖1中裝置之正面圖以說明在本發明之實用中產生疊層外組各級之系列割切之方式；

圖4為取自圖3 Ⅳ－Ⅳ線方向之正面圖；

圖5為與圖3相似之正面圖說明在實行本發明時在外組之下疊層內組各級系列割切之方式；

圖6為取自圖5 Ⅵ－Ⅵ線方向之正面圖；

圖7為相同大小以圖解方式之片斷圖；

圖8為與圖7相似之片斷圖；

圖9為取自疊層正面邊緣方向片斷之放大圖；

圖10為實行本發明之鐵心U型結構以接受線圈之側正面圖；

圖11為根據本發明之變壓器之側正面圖；

圖11A為一片斷圖解說明疊層之吸附時造成之差予以排除；
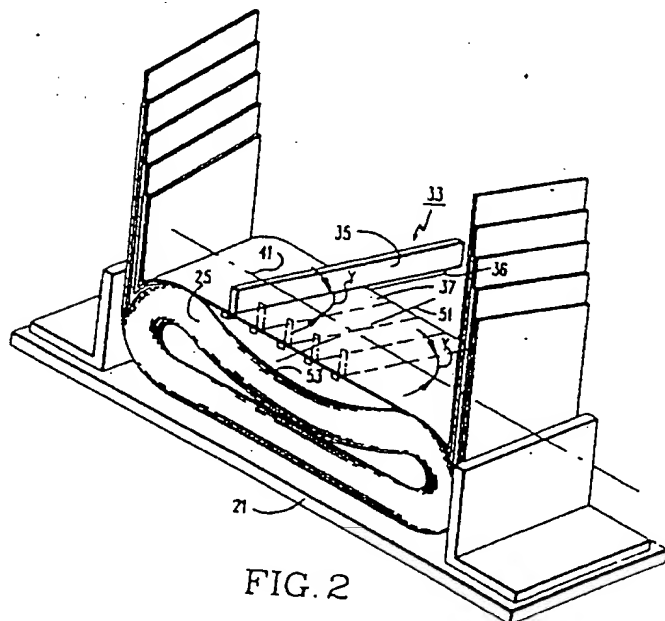
圖12為同質放大之片斷圖；

圖13根據本發明之鐵心中顯示磁通路徑與圖12相似之放大片斷圖；

FIG.1

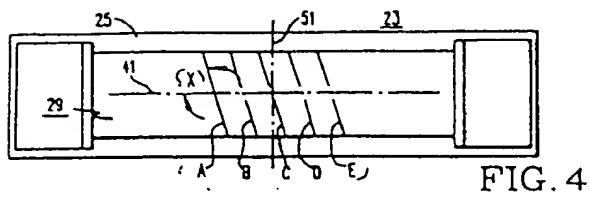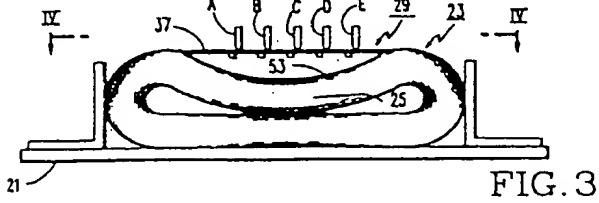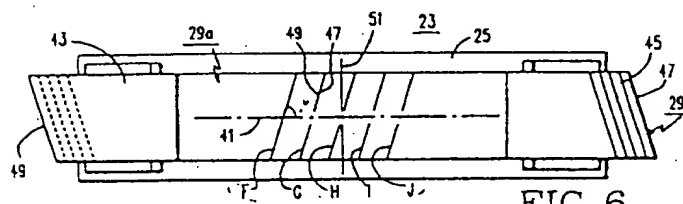

FIG.2

FIG.4

FIG.3

FIG.9

FIG.6

FIG.5

FIG.11A

FIG.8

FIG.7

FIG.10

FIG.11

FIG.12

FIG.13
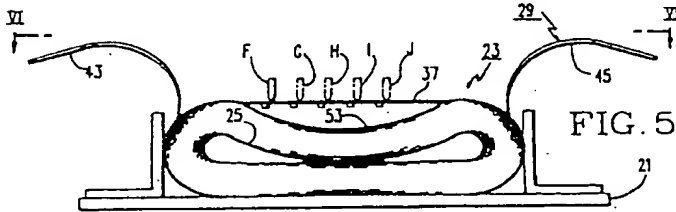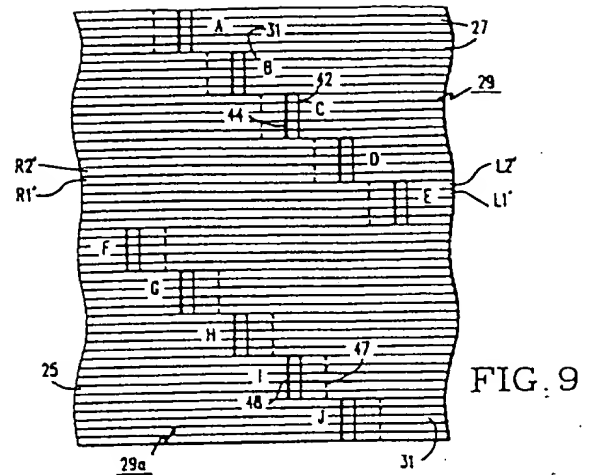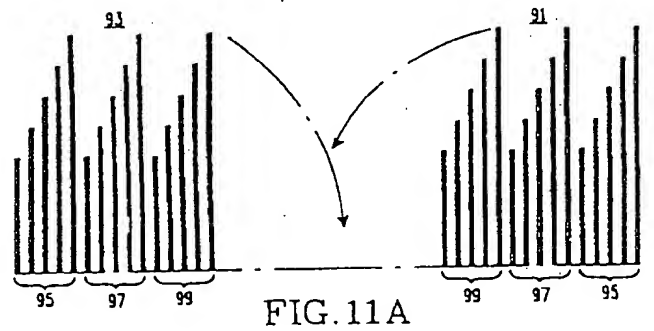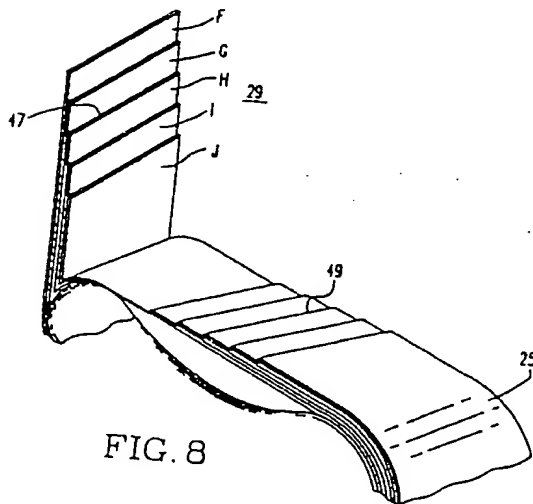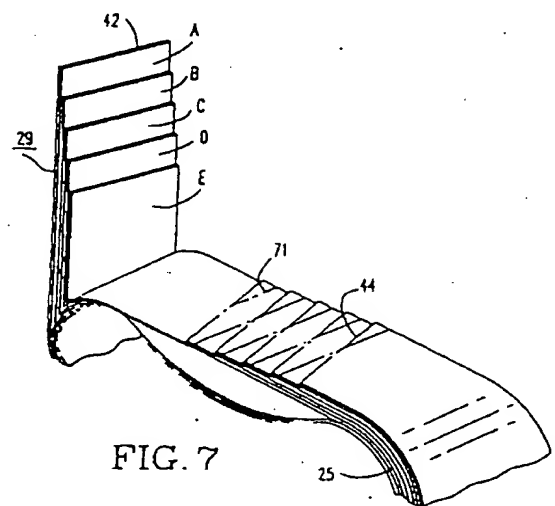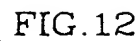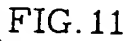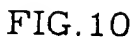
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ABSTRACT OF THE DISCLOSURE

A method of making a transformer having a core
composed of a web of magnetic amorphous metal of small
thickness.

5   The laminations of the core of the transformer
are the stacked turns formed by winding the web into a
spiral having a window in the center. The coils are wound
as integral structures having openings for telescoping the
coils onto the core. For the telescoping, the core is cut
10   and converted into a U-shaped structure on whose arms the
coils are telescoped. The cut joint is a butt-lap-step
joint. To produce such a joint, the laminations are divi-
ded into groups and each group is divided into steps which
are spaced longitudinally of the web. After the coils are
15   telescoped onto the core, the cut ends of the arms of the
U are abutted to form a closed core. The cuts in the lam-
inations that make up alternate groups in the stack are
inclined to the longitudinal center line of the web at a
first angle different from 90°. The cuts in the laminations
20   that make up intervening groups in the stack are inclined
oppositely to the cuts in the alternate groups at an angle
which is also different from 90°. Because of the different
inclination of successive cuts, the undesired abutting of
laminations from different groups during the reclosing of
25   the core is precluded. There is also disclosed a core and
a transformer made by the method.

TRANSFORMERS AND CORES FOR TRANSFORMERS

BACKGROUND OF THE INVENTION

This invention relates to transformers, typically distribution transformers, and it has particular relationship to transformers whose cores are composed of laminations of amorphous metal of small thickness. Typically the thickness of the laminations is of the order of 0.001-inch. While this invention is disclosed herein in detail as applied to a transformer having a core of a wound amorphous metal web of small thickness, as to which this invention has unique advantages, it is understood that the adaptation of the principles of this invention to transformers of other types is within the scope of equivalents of this application and of any patent that may issue on or as a result thereof, typically as the range of equivalents is applied in Graver Tank & Mfg. Co. v. Linde Air Products Co. 339 U.S. 605; 70 Supreme Court Reporter 854 (1950) and interpreted in Uniroyal v. Rudkin-Wiley Corp. 5 USPQ 2d 1434 (CAFC 1988).

Patent 4,709,471 to Milan D. Valencic and Dennis A. Schaffer, assigned to Westinghouse Electric Corporation discloses a method for making the cores of these transformers. Patent 4,761,630 to Frank H. Grimes and Eugenious Hammack, both also assigned to Westinghouse Electric Corporation, discloses structural features of these cores. Valencic teaches that a web of the amorphous metal is wound into a closed spiral core loop or core structure with a window in the center. The turns of the spiral form the

laminations of the core. These laminations forming the
closed core structure are then cut in successive stepped
groups and the closed structure is opened and converted
into a U-shaped structure on whose arms the coils of the
gransformers are telescoped. The arms of the U-shaped
structure are then abutted to reconvert the U-shaped struc-
ture into a closed structure. Grimes discloses a core as
taught by Valencic with lapped steps.

     To explain this invention so that those skilled
in the art will understand it, it is desirable to discuss
Grimes briefly. Figs. 3 and 4 of Grimes show highly en-
larged a fragmentary part of the core as viewed in a direc-
tion perpendicular to the edges of the laminations. If Fig.
3 were extended to show the whole core, it would show the
laminations in a race-track or circular annular shape. The
structure shown is stepped with the steps lapped at their
adjoining laminations. For this application, each unit of
laminations A, B or C or D, E or F is defined as a step and
the steps A, B and C together or D, E and F together are
defined as a group. The laminations are typically only
0.001-inch in thickness so that the step F has a thickness
of 0.007. The thickness of group DEF is 0.021-inch. Grimes
says that there may be as many as thirty laminations in each
step. In this case, each group would have a thickness of
0.09-inch. There may also be less than seven lamenations
in each step; in fact, there may be one lamination in each
step.

     While the teachings of Valencic and Grimes have
made formidable contributions to the transformer art, a
problem has been experienced in the construction of the
core as taught by Valencic and Grimes. In the reconstitu-
tion of the core after the coils are telescoped in its arms,
difficulty has been encountered in matching the separated
ends of the laminations of the groups so that severed ends
of aliminations on one side of a group are joined during
reassembly to the ends of the same laminations on the oppo-
site side of a group. The small thickness of the groups is
a major factor contributing to this problem. In past practice

a group of laminations is at times erroneously matched
with two opposing groups during reassembly. The error
becomes apparent only on completion of the joint reassem-
bled when a spare group of laminations with no matching
5 companion groups remain. For example, with reference to
Fig. 3 of Grimes, the twenty-one laminations on the right
of group ABC instead of being joined to the laminations
on the left of group ABC, are joined to the laminations
on the left of group DEF. When this happens the core as
10 completed has unconnected laminations and must be repro-
cessed. The deficiency is not discovered until after the
core is completed. In addition, after the above-described
error occurs, an opposing error may occur during the con-
tinued reassembly, i.e., the laminations on the left of a
15 group such DEF are joined to the laminations on the right
of a group such as ABC. In this case, the errors are com-
pensating and are not discovered after the core is completed
and the core performance is deteriorated.

          Another problem which arises in connection with
20 cores in one of whose yokes or legs severable joints exist,
has its roots in the principle that among the various fac-
tors that govern the power to excite a transformer is the
local net transverse cross-sectional area reduction which
results from the gaps in the core that form the joint.
25 The net cross-sectional area is reduced and the required
exciting power is increased by the gaps in the laminations
at the joint. In cores formed of laminations of amorphous
metal, this problem is particularly significant because,
in use, such cores are operated at inductions very near to
30 that which produces saturation. Appreciable reduction in
the net transverse cross-sectional area of a core may result
in saturation when the core is used. In a joint containing
a large number of gaps, particularly if the gaps are stacked,
there is a substantial reduction in net cross-sections area
35 and a tendency for saturation to occur with corresponding
adverse effect upon core losses.

Another problem which occurs when a butt-lap-
step core joint as taught by Grimes is reassembled arises
from the tendency of the laminations to adhere to each
other such that more than one group of cut steps may be
5   mismatched and mislocated against a single opposing group.
This error is also only discovered after the joint is com-
pletely reassembled. The error occurs on the side of the
joint where the longest laminations are on top viewing the
joint being reassembled positioned horizontally. The short-
10   er laminations of adjacent groups tend to adhere. The
opposite side of the core where the longest laminations are
at the bottom are "self separating" by groups.

It is an object of this invention to overcome the
above-described drawbacks and deficiencies and to provide
15   a method for accomplishing this purpose. Namely, it is an
object of the invention to provide a method of making a
transformer having a core of amorphous metal, formed by
winding into a spiral a plurality of turns or laminations
of small thickness, which core has a severable joint that
20   is opened to permit the telescoping of coils and thereafter
reclosed by abutting the ends of the severed laminations,
in whose practice, the mismatching of abutted laminations
during the reclosing shall be precluded.

It is also an object of this invention to provide
25   a method of making a transformer in whose practice the trans-
verse cross-sectional area at overlapping laminations at the
gaps produced by severing the laminations shall be enhanced.
It is also an object of this invention to provide a core and
a transformer made by the practice of the method.

30   SUMMARY OF THE INVENTION

In accordance with this invention, there is provi-
ded a core whose joint is formed by cutting the laminations,
not at right angles to the longitudinal center line of the
laminations or to any plane perpendicular to the laminations,
35   but at an angle which differs appreciably from 90°, thus
enabling the cut ends of the same laminations to be readily
identified because they are at the same angle to the center

line. Specifically, the laminations forming the core may
be subdivided into stacked groups. Alternate groups may
be cut biased, i.e., with the cut inclined, not perpendicu-
lar, to the center line, in one direction and the interven-
5   ing groups may be cut biased in the opposite direction,
i.e., with the cut inclined to the center line oppositely
to the cut through the alternate groups. The departure from
perpendicularity may be the same in each direction. But
cores whose joints are formed by cuts of the laminations of
10   alternate groups inclined at different angles to the center
line are within the scope of equivalents of this invention.
In fact, the cuts through the laminations of either the
alternate or the intervening groups may be at right angles
to the center line and the cuts through the laminations
15   of the other groups inclined. The cuts through the steps
of each group are at the same inclination.

The laminations may be cut and the core processed
to produce a transformer as disclosed in Valencic. To pro-
duce the based cuts, the cutter 66 shown in Fig. 6 of Val-
20   encic may be set with the blades 77 and 78 at the appropri-
ate angle to the longitudinal center line of the laminations.
For the purpose of this application, the angle of inclination
will be defined as the acute angle of the cut to the longitu-
dinal center line.

25   It is desirable that the departure of the angle
of cut from the perpendicular to the center line be small,
i.e., angle of inclination to the center line should desir-
ably be large. In practice, an angle of departure of about
3°, i.e., an angle of inclination of about 87° has been
30   found to be satisfactory. The adoption of a large angle
of departure from the perpendicular complicates the setting
of the cutter and has a tendency to cause the brittle lami-
nations to break. It has been found that with the cuts in-
clined at about 87° in opposite directions, the matching of
35   the ends of the lamination which are to be joined is accom-
plished successfully. Practice of the teachings of this
application with the cuts inclined at angles substantially

different from 67° is understood to be within the scope of
equivalents of this application and of any patent which may
issue on or as a result thereof.

In the practice of this invention, the mismatch-
ing of the ends of the several laminations of contiguous
groups is precluded by the opposite biasing of these groups.
This invention also improves the potential towards mechani-
zation of the joint reclosing by effectively separating se-
quential groups in the joint. By cutting first in one
angled direction throughout a group, then reversing the
angled direction throughout the next group and by repeating
this sequence through the whole core, the "herringbone"
geometry can be achieved on a wound core, i.e., an X-ray
through the severed joint taken perpendicular to the surface
of the web forming the laminations would have the appearance
of a "herringbone" or "cross-stitched" joint.

When the core is opened to telescope the coils,
the "opened" sheets are separated into oppositely cut groups
and it becomes impossible to relocate odd and even groups
together. Thus, the assembly problems which have occurred
in the past are eliminated. If a double error occurs, the
joint appears to be correctly closed, but the measured core
losses increase enormously. This error also is eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of this invention, both
as to its organization and as to its method of operation,
together with additional objects and advantages thereof,
reference is made to the following description taken in con-
nection with the accompanying drawings, in which:

Figure 1 is a view in isometric, generally, dia-
grammatic, showing apparatus for practicing this invention
set to produce cuts in the laminations inclined in one dir-
ection to the longitudinal center line of the laminations;

Fig. 2 is a view similar to Fig. 1 with the appa-
ratus set to produce cuts in the laminations inclined in the
opposite direction to the longitudinal center line;

Fig. 3 is a view in side elevation generally diagrammatic of the apparatus shown in Fig. 1 for illustrating the manner in which a series of cuts of steps of the outer groups of laminations are produced in the practice of this

5 invention;

Fig. 4 is a plan view taken in the direction IV-IV of Fig. 3;

Fig. 5 is a view in side elevation similar to Fig. 3 illustrating the manner in which a series of cuts of steps of the inner group of laminations just under the outer group

10 are made in the practice of this invention;

Fig. 6 is a plan view taken in the direction VI-VI of Fig. 5;

Fig. 7 is a fragmental view in isometric, general-

15 ly diagrammatic, showing the manner in which the core structure is reassembled at a group of laminations cut at one inclination;

Fig. 8 is a fragmental view similar to Fig. 7 showing the manner in which the core structure is reassembled

20 at a group of laminations cut at the opposite inclination;

Fig. 9 is a fragmentary view greatly enlarged taken in the direction towards the edges of the lamination essentially in side elevation, showing a portion of a reassembled joint;

25 Fig. 10 is a view in side elevation of a core U-shaped structure formed in the practice of this invention for receiving the coils;

Fig. 11 is a view in side elevation of a transformer in accordance with this invention;

30 Fig. 11A is a fragmentary diagrammatic view for aiding in the explanation as to how error from sticking of laminations is precluded;

Fig. 12 is a fragmentary view in isometric, greatly enlarged and generally diagrammatic, showing the magnetic

35 flux path in a prior-art core through the turns at the junction between steps; and

Fig. 13 is a greatly enlarged fragmentary view similar to Fig. 12 but showing the magnetic flux path in a core according to this invention.

DETAILED DESCRIPTION OF PRACTICE AND EMBODIMENTS OF THIS INVENTION

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The apparatus shown in Figs. 1 through 9 includes a support plate 21 on which a core structure 23 is disposed. The core structure 23 is produced by winding a web 25 of amorphous metal of small thickness into a circularly annular

10 spiral as taught by Valencic. When this spiral is disposed on plate 21 with its axis horizontal, it assumes the generally Figure 8 configuration shown in Figs. 1 through 6.· The turns of the spiral are the laminations 27 (Fig. 9) of the core structure 23.

15 In the practice of this invention, the laminations 27 of the core structure 23 are subdivided as taught by Grimes into groups 29 and 29a (Fig. 9), each group being subdivided into steps 31. The steps of each group are spaced longitudinally along the core structure 23 as shown in Fig.

20 9. Fig. 9 shows successive groups 29 and 29a along the depth of the core structure. Group 29 may be taken as the topmost group and group 29a as the second group from the top assuming that the core structure 23 rests on plate 21 with the axis of the spiral horizontal. In Fig. 9 the steps of

25 the top group 29 are labeled A, B, C, D and E and the steps of the group 29a are labeled F, G, H, I and J. In actual practice of the invention, there are a large number of group 29 and 29a.

As shown in Figs. 1 and 2, the apparatus for prac-
30 ticing the method of this invention includes a cutter 33 having cutting blades 35 and 36. The cutter 33 is the same as is disclosed in Valencic. It is capable of producing a square cut through a predetermined number of laminations or stacks 37 and is positioned and is operable to cut the lami-

35 nations. However, instead of being positioned to produce a cut of laminations at right angle to the longitudinal center line 41 of the web, the blades 35 and 36 are positioned

inclined at an angle X to the center line. The center
line is referred to here as a convenient reference. The
blades 35 and 36 are positioned inclined at angle X to
planes perpendicular to the surface of the web or to its

5   edges where the edges are linear and parallel as shown.
Specifically, the number of laminations in a stack 37 are
the number in a step 31 (Fig. 9). The laminations consti-
tuting each step are raised for cutting by magnets (not
shown) as disclosed in Valencic. This invention may be

10   practiced with cutters other than that shown by Valencic.

In the practice of this invention, the cutter 33
is positioned with its blades inclined at angle X to the
center line for cutting the steps A, B, C, D, E of the top
group 29 (Figs. 3, 4). After each step is cut by the cut-

15   ter, the severed lamination stacks on each side are removed
by magnetic or other means and folded over the adjacent
ends of the core structure 23. The cutter is then advanced
to the right with reference to Figs. 1 and 3 with its
blades 35 and 36 inclined at angle X to the center line

20   41 or the support 21 is advanced to the left and the next
step is raised magnetically or by other means and cut and
its severed parts removed and folded back. This operation
continues until all steps A, B, C, D, E of the top group
are cut. The severed ends 42 and 44 of the laminations of

25   each step are shown in Fig. 4. They are inclined at angle
X to the center line 41.

The core structure 23 is now in the state shown
in Figs. 5 and 6 with the severed parts 43 and 45 of the
top group 29 folded away from the ends of the structure.

30   The cutter 33 is now positioned with its blades 35 and 36
inclined at an angle Y (Fig. 2) to the center line 41. The
inclination at angle Y may be equal and opposite to the in-
clination at angle X. The steps F, G, H, I, J are then cut
and their severed parts folded back in succession. The

35   severed ends 47 and 49 of the steps F through J are shown
in Fig. 6. They are inclined at an angle Y to the center
line 41.

It is emphasized that where the angle of inclination to the center line is large, typically 67°, it is desirable that angles X and Y be equal and opposite. The difference in inclination of the cuts in successive groups is twice the inclination for each group. The capability of recognizing a mismatch is thus facilitated.

The cutter 33 is now repositioned with its blades 35 and 36 at angle X to the center line 41 and the steps 31 of the third group from the top are cut. Then the cutter is again repositioned with its blade at angle Y to the center line and steps of the fourth group from the top are cut. The cutting of odd-numbered groups from the top with cutter blade 35 set inclined at angle X to the center line and even-numbered groups with the cutter blade set inclined at angle Y to the center line is continued until the depth of the core structure is completely penetrated in the region of the cuts. The blades of the cutter are preferably so positioned that the cuts are spaced approximately symmetrically about the transverse center line 51 of the upper portion 53 of the core structure so that the length of the parts of the core structure 23 on each side of the cut region are approximately equal.

Once the width of the core structure 23 is penetrated, the core structure is opened at the cut-through section and the core structure is processed typically as taught by Valencic, particularly with reference to Figs. 10 through 15 and 17 through 22 of this patent. It is understood that this invention is not confined to processing as taught by Valencic and that in the processing of core structure 23 departures from, or modifications of, Valencic's teaching as well as replacement of Valencic by entirely different teaching may be adopted without affecting the scope of this invention.

During the processing, the joint where the core structure 23 is severed is opened and reclosed twice. The first time the core is opened, mechanically manipulated and then reclosed to convert the structure into the desired

shape for the stress-relief anneal. After the anneal,
the structure is reopened a second time in the severed
region forming the U-shaped structure 55, the coils 59
and 61 telescoped on its legs 57 and then reclosed. During
5   the reclosing, the cut ends 42 and 44 (Fig. 4) and 47 and
49 are abutted and lapped at the junctions between adjacent
steps starting from the lowermost group and continuing
through the uppermost group assuming the axis of the core
is horizontal.

10   During the processing, the core structure is
converted into the self-supporting structure 55 shown in
Fig. 10 with arms 57. While the core structure 57 is self
supporting, the ends of the core structure which form the
joint in the cut region 63 can be manipulated from the
15   open position with reference to Fig. 10 to the closed posi-
tion.

            It is essential, particularly during the second
reclosing after the coils are telescoped on the legs that
mismatching between adjacent groups be precluded and this
20   is accomplished in the practice of this invention as shown
in Figs. 7 and 8. Fig. 7 shows the reclosing of the lamina-
tion of a group 29 such as the group made up of the steps A,
B, C, D, E (Fig. 9). The inclined full lines representing
ends 42 and 44 are assumed to represent the ends of steps A,
25   B, C, D, E and not the ends of individual laminations. The
steps are folded over in sequence from E to A. It is seen
that the end 42 of each step is contiguous to and aligned
with end 44 of the same step. Fig. 8 corresponds to the
group 29 adjacent to the group represented in Fig. 7 whose
30   steps are F, G, H, I, J. In this case, the cuts are inclined
oppositely to the cut for the group of Fig. 7. In this case,
the ends 47 of the steps J through F are contiguous to and
aligned with the ends 49. If an attempt were made to abut
the left-hand end of group 29 shown in Fig. 7 with the right-
35   hand end of group 29a shown in Fig. 8, the ends 49 would be
inclined as represented by the broken lines 71 in Fig. 7 and
the misalignment would at once become obvious.

Prior-art practice has been confronted by the
major problem that during reassembly there is a tendency
for the cut laminations on one side of two groups to adhere
so that the ends of the outer of two adhering groups on one
side may be joined to the ends of one group on the opposite
side. In the practice of this invention, the joining of
two groups to one group is precluded.

Reference is made to Fig. 11A for an understanding
of this advantage. Fig. 11A shows the ends 91 and 93 of
three groups 95, 97, 99 which are to be joined during re-
closing. There are five steps in each group, each step
being represented by a single line. It is assumed that
group 95 is on top and group 99 on the bottom. The cuts
in group 97 are inclined oppositely to the cuts in groups
95 and 99. It has been found that the adhering occurs when
the longest sheets are on top, assuming the core structure
is positioned with its axis horizontal. It may be assumed
that the laminations of groups 95 and 97 at the end 91 have
adhered but there has been no adhesion of the laminations
of groups 95 and 97 at end 93. An attempt will then be made
to join group 97 of 91 to group 95 of end 93. Since the
cuts in group 97 are inclined oppositely to the cuts in
group 95, the mismatch by the erroneous joining of the ends
of groups 95 and 97 will be precluded.

The advantageous aspect of this invention with
respect to the reduction of the crowding of the flux lines
will now be explained with reference to Figs. 12 and 13.
Fig. 12 corresponds to a core structure in which the cuts
42a-44a are at right angles to the longitudinal center line
as taught by prior art and Fig. 13 corresponds to a core
structure in which the cuts 42-44 are inclined to the center
line 41 in accordance with this invention. In this discus-
sion, it is assumed that the lamination or group of lamina-
tions R1 and R2 and R1' and R2' are in a core of a trans-
former which is in operation.

In each view, the transition lamination R1 and R2
and R1' and R2' at the junction between adjacent steps, for

example between step E and step D, of group 29 are shown.
The flux lines f1 and f2 are shown as flowing through R1
and R2 from L1 and L2 through the laminations R2 and R1
shown in Fig. 12 and from L1' and L2' through the lamina-
tions R2' and R1' shown in Fig. 13; in both cases from left
to right. The transition laminations in Figs. 12 and 13
are reversed with reference to Fig. 9. To aid in the under-
standing of the invention, dimensions are assumed; it is
assumed that the width of the cut is 0.25-inch and the over-
lap 0.375-inch. It is also assumed that the inclination of
the cut shown in Fig. 13 is at 60° to the center line.

          With reference to Fig. 12, flux f1 flows through
L1 until it reaches gap G1 where it flows into and through
R2. It then returns to R1 when it passes gap G1. Flux f2
flows through L2 until it reaches gap G2 where it flows into
through L1 until it passes gap G2 when it flows back through
R2. Crowding of the flux takes place in the regions in L1
at gap G2 and R2 at gap G1 where the flux flows through com-
mon channels.

          One way to minimize this flux crowding and the
resulting saturation and core loss increase is to spread
the flux crowding over as large an area as practicable. In
the prior art as shown in Fig. 12, the crowding is spread
over an area of 1.0 square inch 0.25 x 4. Once flux f2 pass-
es gap G2, it reenters R2 before reaching the gap G1. This
reentry of flux f2 takes place over 0.375-inch. The area is
0.375 x 4 = 1.50 square inches. The flux crowding can be
reduced by increasing the overlap. For example, for overlap
of 0.5-inch, the area is 2 inches. But because of the
limited area over which the transition is located, any in-
crease in overlap would reduce the number of steps which
may occur.

          In the practice of this invention, the flux f2'
flows from lamination L2' into lamination L1' at gap G2'
and reenters laminations R2' after it passes gap G2'. Flux
f1' when reaching gap G1' flows through R2'. It reenters
R1' after passing gap G1'. In the practice of this invention

the inclination is 60° and the cut is at 60° to the center
line 41. The area above gap 32' is 0.25 x 4.6 or 1.15
square inches. The area over which flux f2' reenters R2'
is .375 x 4.6 = 1.73 square inches. The increase in area

5   in each case is produced without reducing the number of
steps within the region. The smaller the inclination of the
cut to the center line, the greater the area over which the
crowding is spread.

While preferred embodiments and preferred practice

10 of this invention have been disclosed herein, many modifica-
tions thereof are feasible. This invention is not to be
restricted except insofar as is necessitated by the spirit
of the prior art.

1.   An improved transformer core having a butt-lap-step transformer core joint, said transformer-core joint comprising a plurality of bias-cut laminations cut from a continuous web wound generally in a spiral, the said cut laminations being rejoined at their ends by butted joints after coil means are telescoped on said core, said plurality of laminations being divided into a plurality of groups of laminations, each group including a predetermined number of laminations, said bias cut precluding mismatching of butted lamination ends in the assembly of said core after said coil means has been telescoped thereon and lengthening the adjacent flux path at said buffed joints, said core being formed by superimposing successive groups of the laminations in a generally spiral configuration, the bias cuts in laminations of alternate groups being biased at a predetermined inclination to the longitudinal center line of said laminations and the bias cuts on the intervening groups being biased at an opposite inclination to the center lines of said laminations.

2.   The core of claim 1 wherein each group of laminations is subdivided into steps and the bias cut in the laminations of each group comprising a plurality of stepped cuts at the same bias.

3.   The core of claim 1 wherein each group of laminations is subdivided into steps, the bias cuts in the laminations of each alternate groups comprising a plurality of stepped cuts at the predetermined inclination and the bias cuts in the laminations of each intervening group comprising a plurality of stepped cuts at the inclination opposite to said predetermined inclination.

4. A transformer including a core having coil
means telescoped thereon, said core including a plurality
of laminations of amorphous metal of small thickness wound
generally in a spiral and defining a closed curve structure
having a window within, the said coil means being wound as
an integrated structure encircling the core, the said core
having a butt-lap-step joint allowing the opening of said
core to permit telescoping of said coil means and the re-
closing of said core after said coil means are telescoped
thereon, said butt-lap-step joint being formed by cutting
in stepped relationship the laminations of groups in suc-
cession, each group comprising a predetermined number of
said laminations to open said core and abutting the ends of
said cut laminations of each group to reclose said core after
the coil means is telescoped thereon, the cuts in said lami-
nations being biased inclined at a first predetermined angle
appreciably different from 90° to the longitudinal center
line of said laminations for laminations of alternate groups
in said succession and inclined oppositely to said predeter-
mined angle at a second predetermined angle appreciably
different from 90° to said longitudinal center line of groups
intervening between said alternate groups.

5. The transformer of claim 4 wherein each group
of the alternate groups and the intervening groups is sub-
divided into a plurality of steps and the cut in the lamina-
tions of each group comprises stepped cuts in laminations
of the steps of each group, the angle and inclination to
the center line of the lamination of the stepped cut for
each group being the same.

6. The method of making a transformer having a
core and coil means whose turns are wound into an integrated
coil structure having an opening therein for telescoping
onto said core, said core being formed of a web of magnetic
amorphous metal of small thickness, the said method including:

(a) winding said web into a generally spiral core structure having a plurality of superimposed laminations about a window;

(b) subdividing said core structure into groups of laminations, said groups being stacked to form said core structure;

(c) producing first cuts through the laminations of each of alternate groups in said core structures, each said cut in the laminations of alternate groups along said core structure being inclined to the center line of said web in one direction at an angle appreciably different from 90°;

(d) producing second cuts through the laminations of each of the groups along said core structure intervening between alternate groups, each of said second cuts in the laminations of said intervening groups along said core structure being inclined to the center line of said web in a direction opposite to said one direction at an angle appreciably different from 90°;

(e) separating said laminations at said cuts and converting said core structure into a generally U-shaped structure whose arms terminate in said cuts;

(f) telescoping said coil structure in the arms of said U-shaped structure; and

(g) guided by the difference between the inclination of the severed ends of the laminations, rejoining the ends of the laminations of said groups, group by group, by abutting substantially only the ends of the lamination of each group only to the opposite ends of the lamination of the same group from which said first-named ends were severed, precluding the joining of the ends of the laminations of one group to the ends of the laminations of adjacent groups.

7. The method of making a transformer having a core and coil means whose turns are wound into an integrated coil structure having an opening therein for telescoping onto said core, said core being formed of a web of magnetic amorphous metal of small thickness, the said method including:

(a)   winding said web into a generally spiral
core structure having a plurality of superimposed lamina-
tions about a window;

(b)   subdividing said core structure into groups
of laminations, said groups being stacked to form said core
structure;

(c)   producing first cuts through the laminations
of each of alternate groups in said core structure, each
said cut in the laminations of alternate groups along said
core structure being inclined to the center line of said
web in one direction at an angle appreciably different from
90°;

(d)   producing second cuts through the laminations
of each of the groups along said core structure intervening
between alternate groups, each of said second cuts being
at a different angle to the longitudinal center line of said
web through said first cuts;

(e)   separating said laminations at said cuts and
converting said core structure into a generally U-shaped
structure whose arms terminate in said cuts;

(f)   telescoping said coil structure in the arms
of said U-shaped structure; and

(g)   guided by the difference in the angle of in-
clination to the longitudinal center line of the web of the
first cuts and the second cuts, rejoining the ends of the
laminations of said groups, group by group, by abutting sub-
stantially only the ends of the lamination of each group
only to the opposite ends of the lamination of the same group
from which said first-named ends were severed, precluding
the joining of the ends of the laminations of one group to
the ends of the laminations of adjacent groups.

8.   The method of claim 7 including subdividing
each group into steps displaced longitudinally from each
other along the web and producing first and second cuts
each of which comprises cuts in the steps of each group dis-
placed longitudinally along the web but at first angle to
the longitudinal center line of the web for the alternate
groups and at the second angle to the longitudinal center
line of web for the intervening groups.

9. The method of making a transformer with
reduced losses, the said method including:

    (a) winding a web of magnetic amorphous metal
into a spiral structure having a window in the center;

    (b) subdividing the turns of said spiral into
groups, each group being subdivided into steps;

    (c) producing a series of cuts through the steps
of each group in a region of said spiral, the cuts through
the steps of each group being spaced longitudinally along
said web in a predetermined direction; the cuts for each
step of a group and the cut of the succeeding step termina-
ting such that the last turn of a step of a group and the
first turn of said succeeding step of said group overlap,
whereby magnetic flux flowing through said last turn and
through said first turn will be conducted together through
one and the other of said last and first turns in the region
of said cuts, producing crowding of the flux in said region,
the said cuts being produced through all groups of said web;

    (d) opening said spiral at said cuts;

    (e) thereafter converting said spiral into a
U-shaped structure;

    (f) telescoping coils on the arms of said
U-shaped structure; and

    (g) reclosing said groups in the region of said
cuts, thus producing a transformer having the reclosed spiral
structure as a core;

the said method being characterized by that the
cuts through the steps are inclined to said longitudinal
center line at an angle appreciably different from 90°,
whereby the area of the core in the region of said crowding
of said flux is increased.

10. The core of claim 1 wherein the angles of
inclination of the bias cuts of the alternate groups and the
intervening groups are substantially equal and opposite and
depart from 90° to the center line by a small magnitude.

11. The core of claim 1 wherein the core is formed by superimposing successive groups of the laminations in a generally spiral configuration, the bias cuts in at least alternate groups or the groups intervening between the alternate groups being inclined at an angle appreciably different from 90° to the center line web.

12. The transformer of claim 4 wherein the angles of inclination of the bias cuts of the alternate groups and the intervening groups are substantially equal and opposite and depart from 90° to the center line by a small magnitude.

13. The method of claim 6 wherein the angles of inclination of the first cuts and the second cuts are substantially equal and opposite and depart from 90° to the center line of the web by a small magnitude.